

EARBUD DEVICES WITH CAPACITIVE SENSORS

BACKGROUND

[0001] This relates generally to electronic devices, and, more particularly, to electronic devices such as earbuds.

[0002] Electronic devices such as earbuds contain audio circuitry and speakers for playing audio content for a user. In a typical scenario, the earbuds receive audio content wirelessly from a cellular telephone. **10**

[0003] It can be challenging to perform music playback operations and other device functions using a pair of earbuds. In some situations, a user's cellular telephone is not accessible, making it difficult to pause and resume audio content when desired. Providing user input to the earbuds to control functions such as audio playback can be difficult due to their small size.

SUMMARY

[0004] Audio playback functions and other operations may be controlled using a controller in an earbud that analyzes sensor data to determine the operating state of the earbud. If, as an example, a user removes an earbud from the user's ear, the controller can automatically pause audio playback.

[0005] An earbud may have a housing. The housing may have an ear portion configured to be received within an ear of a user. The housing may also have an elongated stalk portion that protrudes away from the ear portion. Capacitive sensor electrodes may be formed both on the ear portion and the stalk portion.

[0006] During operation, the controller may gather capacitive sensor data from the capacitive sensor electrodes and may gather data from non-capacitive-sensing sensors. Using this data, the controller can classify an operating mode of the earbud.

[0007] The controller may take actions such as pausing or resuming audio playback using the results of classification operations such as information on whether an earbud is in an in-ear state or an in-finger (out-of-ear) state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic diagram of an illustrative electronic device in accordance with an embodiment.

[0009] FIG. 2 is a rear perspective view of an illustrative ear bud in accordance with an embodiment.

[0010] FIG. 3 is a front perspective view of the illustrative ear bud of FIG. 3 in accordance with an embodiment.

[0011] FIG. 4 is a side view of an illustrative ear bud showing how a flexible printed circuit that includes capacitive sensor circuitry can be mounted within the interior of an earbud housing for the ear bud in accordance with an embodiment.

[0012] FIG. 5 is a perspective view of an illustrative flexible printed circuit with capacitive sensor electrodes in accordance with an embodiment.

[0013] FIGS. 6 and 7 are cross-sectional side views of portions of an illustrative flexible circuit with capacitive sensor electrodes, a ground electrode, and an active shield electrode in accordance with an embodiment.

[0014] FIG. 8 is a cross-sectional side view of a portion of an ear bud having capacitive sensor circuitry on a flexible printed circuit that is bent by wrapping the flexible printed

around an axis so that the flexible printed circuit and the capacitive sensor circuitry on the flexible printed circuit conform to a curved inner surface of a housing wall in accordance with an embodiment.

[0015] FIG. 9 is a graph showing how control circuitry in an ear bud can detect when the ear bud is in the ear of a user in accordance with an embodiment.

[0016] FIG. 10 is a flow chart of illustrative operations involved in using an ear bud in accordance with an embodiment.

DETAILED DESCRIPTION

[0017] An electronic device such as an earbud may be provided with sensors. The sensors may include capacitive sensing circuitry and other sensing circuitry that monitors how the device is positioned relative to the body of a user. The sensors may, for example, include capacitive sensing circuitry and/or other sensors for detecting when the device is positioned in the user's ear. Based on information from the sensors, suitable action can be taken by control circuitry in the device. For example, audio playback may be controlled.

[0018] In general, the electronic device may be any suitable type of device that includes sensors. Illustrative configurations in which the electronic device is an earbud are sometimes described herein as an example.

[0019] FIG. 1 is a schematic diagram of an illustrative electronic device such as an earbud. As shown in FIG. 1, earbud **10** may communicate wirelessly with external equipment such as electronic device **14** using wireless link **28**. Wireless signals for link **28** may be light-based signals, may be acoustic signals, and/or may be radio-frequency signals (e.g., wireless local area network signals, Bluetooth® signals, radio-frequency signals in cellular telephone band, signals at 60 GHz, near field communications signals, etc.). Earbud **10** and device **14** may have antennas and wireless transceiver circuitry for supporting wireless communications over link **28** (e.g., input-output circuitry in earbud **10** such as devices **22** may include antennas, wireless transceiver circuitry, and/or other communications circuitry for supporting wireless communications over link **28**). Earbud **10** may have the same capabilities as device **14** (i.e., earbud **10** and device **14** may be peer devices) or earbud **10** may include fewer resources or more resources than device **14**.

[0020] Illustrative earbud **10** of FIG. 1 has control circuitry **20**. Control circuitry **20** may include storage and processing circuitry for supporting the operation of earbud **10**. The storage and processing circuitry may include storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **20** may be used to control the operation of earbud **10** (see, e.g., controller **20B**). The processing circuitry may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors, power management units, audio chips (e.g., chips with audio amplifiers that can be selectively assigned to play right channel audio in a first ear speaker of earbud **10** and left channel audio in a second ear speaker or vice versa), application specific integrated circuits, etc.

[0021] Earbud **10** may include capacitive sensors and/or other sensors **26**. Sensors **26** may include optical sensors such as optical proximity sensors (e.g., sensors that include an infrared light source such as an infrared light emitting